577

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PHOTOGRAMMETRY AIDS THE PENNSYLVANIA TURNPIKE

by G. B. Gilbert

SURVEYING AND MAPPING
DIVISION

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PHOTOGRAMMETRY AIDS THE PENNSYLVANIA TURNPIKE

G. B. Gilbert[1]

One of the major links with Delaware Valley, U. S. A., today is the Pennsylvania Turnpike, spanning the State from the Ohio Border to this booming new industrial area in the east. Last year 12,000,000 passenger cars and trucks traveled the Turnpike, and gross income was almost $23,000,000.

Built at a cost of nearly a quarter billion dollars, the Turnpike now is 327 miles in length. This is 40 per cent of the existing toll road mileage in the whole United States.

The original 160-mile section of the Pennsylvania Turnpike, from Middlesex to Irwin, was constructed in 1940; the 100-mile Philadelphia Extension, connecting Middlesex with Valley Forge, was completed in 1950; and the 67-mile Western Extension, linking Irwin with the Ohio State Line, was opened in 1951.

Two new spurs are presently under construction—the 33-mile Delaware River Extension, which will connect Valley Forge with a point near the Delaware River; and the 110-mile section of the Northeastern Extension, which will link Plymouth Meeting, near Norristown, with a point north of Scranton.

Present plans call for the construction of a new bridge across the Delaware River, which was jointly financed and will be constructed and operated by the Pennsylvania Turnpike Commission and the New Jersey Turnpike Authority. This will be the connecting link between the two super-highways.

Future authorized extensions of the Pennsylvania Turnpike System include the construction of the Northwestern Extension, which includes a spur running east and west the width of Erie County; the Gettysburg Extension; and the remaining portions of the Northeastern Extension, which include lateral connections running east to the Delaware River and west to the Susquehanna River.

When finally completed, the Pennsylvania Turnpike System will total more than 750 miles, giving Pennsylvania—the pioneering State—the greatest system of its type of highway construction in the world.

These statistics give some picture of the scope of this project, and we should like to discuss here our experience in an important phase of this work: the surveying and mapping for the Turnpike design and location. This first step can advance construction by many days and save many headaches; and we propose to report on the type of maps we used, the methods employed in compiling them, and the uses made of the maps.

The original section of the Turnpike was studied entirely by ground survey methods, which included re-establishment of all of the old South Penn Railroad Right-of-Way alignment and tieing said alignment to the various studies made by us.

At that time we had no benefit of aerial photography and it was only in the later stages of design that we first obtained and made use of the aerial photographs as flown for the Agricultural Adjustment Administration.

Since 1947 all mapping for the Turnpike extensions has been done by aerial photogrammetric methods. We first used the aerial survey because at that

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time field engineering manpower and office engineering personnel necessary for a conventional survey were in short supply and not readily available. We contracted for an aerial survey covering a route strip one mile wide, from Harrisburg to Philadelphia. It was delivered in 145 days, from November 1 to March 25.

For the extension from Irwin to the Ohio Line, a route strip one mile wide and 68 miles long was delivered in 70 days. We estimated that this aerial survey was done five times faster than ground surveys, and at approximately 20 per cent of the cost of ground surveys.

In 1952 we contracted for 34.5 miles of mapping from King of Prussia to Bristol, which was completed in 60 days; and in 1953 we called on the air-mappers for an additional 149 miles from the Delaware River Extension to the New York-Pennslyvania Line. All these surveys were executed by Aero Service Corporation.

The flights for those surveys were made within a few days, without dotting the landscape with surveyors; and later maps and photos were used for land acquisition.

We like the speed of the air survey. We have a dollar-and-cent reason for liking it; that's the interest on Turnpike bonds. We want to start traffic rolling and revenue coming in just as soon as we can after the bonds are issued, because the interest charges start running from the first day of the sale of the bonds.

Not only does the air survey move faster than ground studies, but we find it expedites many phases of our route studies. On the original Turnpike, covering 200 miles from Pittsburgh to Harrisburg, we spent 130 weeks on the ground surveys which, if mapped from the air, might have been completed in 30 weeks.

Aerial surveys are a very useful tool, in our experience, to help to find answers to many factors in our route selection:

1) alignment
2) topography and grade
3) number and types of bridges
4) right-of-way problems
5) scenic values
6) relation to existing highways
7) location of interchange areas
8) alternate route studies
9) tunnel locations

First step in the aerial survey is the study of contact prints of the aerial photographs at a scale of approximately 1 inch equals 1,000 feet. We use this for reconnaissance. Usually several alternate routes are photographed, and to study each of these routes thoroughly on the ground would be very expensive and time-consuming. However, the photo-reconnaissance covers a 9,000-foot wide strip which can be studied under the stereoscopes by our engineers. These photos, and spot studies at certain points, make it possible to narrow the route to a mile-wide strip, which then is mapped. Best results are obtainable photographically only in the fall or spring, when the leaves are off the trees.

The mapping plane flies at an altitude of more than a mile above the selected route, making exposures at intervals of about half a mile, or about every 20 seconds. This produces a forward overlap of 55 per cent, and the overlapping coverage at the side is about 35 per cent.

After the prints are made, a set is given to the airmapper's field survey crews. They establish the necessary horizontal and vertical control data. These men use precise theodolites, and frequently combine traverse and bench leveling into a single operation. All control is tied into monuments established by the Coast and Geodetic Survey for both the horizontal and vertical positions.

After the field survey parties have established the necessary photo control points for the areas photographed, the compilation of the topographic maps goes forward with the aid of precise stereoplotting instruments. In addition to the topographic detail, a wealth of cultural features seen on the air photos is added to the topo maps. Roads to their proper width, streams, buildings, wooded areas, transmission lines, and similar details are clearly seen by the stereoplotter operator for recording on the map sheets.

The finished maps are inked linen topographic drawings, complete in cultural detail, to a scale of 1 inch equals 200 feet, showing contours at 5-foot intervals. Identification of dwellings is shown by symbol; and spot elevations are indicated at road and railroad intersections, summits, depressions and saddles. Buildings with any side equal to 60 feet or more are shown in correct outline, but others are indicated by a 25 x 25 foot square symbol. Other symbols, such as those for streams, quarries, and swamps, conform closely to standard practices.

The photogrammetric engineers were called upon to deliver collateral photographic information which increased the usefulness of the contour maps. This collateral material included photo-mosaics (or photo-maps) at a scale of 1 inch equals 400 feet, corresponding to the topographic map sheets in boundaries; a set of contact prints from the mapping photo negatives at a scale of 1 inch equals 400 feet; plus a tabulation describing the elevations and coordinates of the aerial surveyors' ground control points.

How were these topographic maps used? With them we dealt with general alignment problems; we studied run-off problems and the preliminary design of culverts. They were useful in cut and fill studies and earth-work problems generally. We made preliminary estimates of quantities with the aid of the maps.

The locations of interchanges and service stations were planned with the aid of these maps; and they were useful also in the planning and location of our routes in suburban areas and heavily built-up areas, and in avoiding conflict with cemetaries. Finally, they have a broad usefulness in discussing plans with citizens of the community and with members of our State Government, for these contour maps and photo maps embrace a wide route strip. We can show the considerations that lead to the route choice. You cannot please everyone in these matters; but we can show the several of our studies and make clear that this is not a matter of arbitrary decision.

We found the control data established by the photogrammetrists was useful later for our own crews. We tied our study or adopted line to the horizontal ground control established to third order or better accuracy by the airmappers, and we found it a satisfactory horizontal base.

How accurate were the aerial maps? We found them sufficiently accurate for the purposes to which they were put. Vertical and horizontal accuracies were within the National Map Accuracy Standards, on our field checks. These standards provide that 90 per cent of all elevations be correct within one-half contour interval, and that the remaining 10 per cent not be in error by more than one contour interval, and that 90 per cent of horizontal positions must be within 1/40 inch (map scale) of their true coordinate position.

Finally, we made one more use of the air surveyor—to maintain a continuing inventory or progress report for the Turnpike construction. During 1953, on the fifteenth of each month, a photo-plane flew the length of the construction area twice. The low flight, at an altitude of about 750 feet, gave us our progress studies; the higher altitude survey, at about 2,000 feet, gave us useful right-of-way information. The photos were made as an overlapping series of oblique views, and the image area in the background in one picture was seen as the image area in the foreground of the next picture. They were bound in an 8-1/2 x 11 inch booklet, in sequence, so that by flipping the pages you have a detailed, bird's-eye view of the entire project from beginning to end. The project was flown within 90 minutes maximum, and for all practical purposes we have an almost simultaneous inventory time for the entire project. We have resumed these photo-inventories this past spring, and they continue to yield valuable basic data for us.

A few years ago, when we made a comparison of costs for the construction of the original Turnpike and the two extensions then operating, we found that every cost had increased except one: the mapping cost. The air survey cost substantially less than the ground surveys.

This is not to suggest that photogrammetric methods will eliminate all survey and mapping problems, or that the transit and tape is headed for the Smithsonian Institute. There are limits to its usefulness, and we agree with the photogrammetric engineer when he argues for a conservative application of the method. Based on our experience with the method, we feel that the maps might be improved by being prepared to a larger scale and more accurately showing the contours to a more narrow contour interval, and made more useful by providing a way of projecting adjacent negatives corrected to horizontal projection and adjusted to comparable scale onto a screen for the purpose of stereopic viewing by groups of engineers. We believe that highway engineers and photogrammetrists together should explore the possibilities of new uses for these maps, such as coordinating color, mottling and growth with soil, water and rock formation in order that some predictions of geology and soil conditions could be more readily-established from the photographs themselves.

In conclusion, we find aerial photogrammetric methods are:

1) dependable
2) faster
3) more complete and detailed
4) cost less
5) avoid premature disclosure of routings

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The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

VOLUME 79 (1953)

DECEMBER: 359(AT), 360(SM), 361(HY), 362(HY), 363(SM), 364(HY), 365(HY), 366(HY), 367(SU)[c], 368(WW)[c], 369(IR), 370(AT)[c], 371(SM)[c], 372(CO)[c], 373(ST)[c], 374(EM)[c], 375(EM), 376(EM), 377(SA)[c], 378(PO)[c].

VOLUME 80 (1954)

JANUARY: 379(SM)[c], 380(HY), 381(HY), 382(HY), 383(HY), 384(HY)[c], 385(SM), 386(SM), 387(EM), 388(SA), 389(SU)[c], 390(HY), 391(IR)[c], 392(SA), 393(SU), 394(AT), 395(SA)[c], 396(EM)[c], 397(ST)[c].

FEBRUARY: 398(IR)[d], 399(SA)[d], 400(CO)[d], 401(SM)[c], 402(AT)[d], 403(AT)[d], 404(IR)[d], 405(PO)[d], 406(AT)[d], 407(SU)[d], 408(SU)[d], 409(WW)[d], 410(AT)[d], 411(SA)[d], 412(PO)[d], 413(HY)[d].

MARCH: 414(WW)[d], 415(SU)[d], 416(SM)[d], 417(SM)[d], 418(AT)[d], 419(SA)[d], 420(SA)[d], 421(AT)[d], 422(SA)[d], 423(CP)[d], 424(AT)[d], 425(SM)[d], 426(IR)[d], 427(WW)[d].

APRIL: 428(HY)[c], 429(EM)[c], 430(ST), 431(HY), 432(HY), 433(HY), 434(ST).

MAY: 435(SM), 436(CP)[c], 437(HY)[c], 438(HY), 439(HY), 440(ST), 441(ST), 442(SA), 443(SA).

JUNE: 444(SM)[e], 445(SM)[e], 446(ST)[e], 447(ST)[e], 448(ST)[e], 449(ST)[e], 450(ST)[e], 451(ST)[e], 452(SA)[e], 453(SA)[e], 454(SA)[e], 455(SA)[e], 456(SM)[e].

JULY: 457(AT), 458(AT), 459(AT)[c], 460(IR), 461(IR), 462(IR), 463(IR)[c], 464(PO), 465(PO)[c].

AUGUST: 466(HY), 467(HY), 468(ST), 469(ST), 470(ST), 471(SA), 472(SA), 473(SA), 474(SA), 475(SM), 476(SM), 477(SM), 478(SM)[c], 479(HY)[c], 480(ST)[c], 481(SA)[c], 482(HY), 483(HY).

SEPTEMBER: 484(ST), 485(ST), 486(ST), 487(CP)[c], 488(ST)[c], 489(HY), 490(HY), 491(HY)[c], 492(SA), 493(SA), 494(SA), 495(SA), 496(SA), 497(SA), 498(SA), 499(HW), 500(HW), 501(HW)[c], 502(WW), 503(WW), 504(WW)[c], 505(CO), 506(CO)[c], 507(CP), 508(CP), 509(CP), 510(CP), 511(CP).

OCTOBER: 512(SM), 513(SM), 514(SM), 515(SM), 516(SM), 517(PO), 518(SM)[c], 519(IR), 520(IR), 521(IR), 522(IR)[c], 523(AT)[c], 524(SU), 525(SU)[c], 526(EM), 527(EM), 528(EM), 529(EM), 530(EM)[c], 531(EM), 532(EM)[c], 533(PO).

NOVEMBER: 534(HY), 535(HY), 536(HY), 537(HY), 538(HY)[c], 539(ST), 540(ST), 541(ST), 542(ST), 543(ST), 544(ST), 545(SA), 546(SA), 547(SA), 548(SM), 549(SM), 550(SM), 551(SM), 552(SA), 553(SM)[c], 554(SA), 555(SA), 556(SA), 557(SA).

DECEMBER: 558(ST), 559(ST), 560(ST), 561(ST), 562(ST), 563(ST)[c], 564(HY), 565(HY), 566(HY), 567(HY), 568(HY)[c], 569(SM), 570(SM), 571(SM), 572(SM)[c], 573(SM)[c], 574(SU), 575(SU), 576(SU), 577(SU), 578(HY), 579(ST), 580(SU), 581(SU), 582(Index).

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c. Discussion of several papers, grouped by Divisions.
d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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